SUSTAINING THE ARMY TRAINING MISSION BY RE-THINKING DECISION SUPPORT SYSTEMS: SHIFTING FROM DECISION-MAKING INDIVIDUALS TO SENSE-MAKING AGENTS

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ABSTRACT

Decision Support Systems (DSS), as computerized systems that implement and support complex decision processes, have evolved significantly during the last four decades. However, this evolution has been dominantly bottom-up and technology-driven, with new emerging technologies supporting the traditional concept of decision making as a basically rational process (Simon 1960). In an effort to reconceptualize decision making, this paper follows a top-down approach, starting with a new conceptual framework and then exploring the technologies and tools that can support it. To this end, the paper proposes four major conceptual shifts: a pragmatic shift from problems in the mind to problematic situations in the world, a constructive shift from passive decision making to active sense making, a normative shift from accuracy and certainty to plausibility and transparency, and a technical shift in our understanding of technology as enabler to technology as transformer of human activity. These shifts are in harmony with current theoretical trends in DSS and related disciplines — e.g., the growing emphasis on multiple perspectives in DSS, on multi-agent systems in Artificial Intelligence, on distributed cognition in psychology, and on sense making in organization science (Weick 1995, 2001). By focusing our attention on the collective, distributed, and constructive character of cognition, the framework that results from these shifts provides a useful way of thinking about DSS. Furthermore, ideas from science and technology studies portray a tightly interwoven picture of technologies and their social and organizational context, which is very different from the traditional view of technologies as mere tools. Brought to the realm of DSS, this calls for a fresh look at the relationship between information technologies and decision-making processes.

1. INTRODUCTION

Decision Support Systems (DSS) have evolved significantly during the last four decades. However, their capabilities are still very limited. Elgarah et al. (2002), for instance, writing on a project to develop a DSS for urban infrastructure decision making for the city of Houston, report that they "*know of no DSS design methodology suitable for use in such a complex, conflict-filled situation as this.*" This is an alarming observation in the face of decades of research and practice on DSS. An overview of the development of DSS reveals the dominance of a techno-centric view that portrays technology as the panacea and silver bullet to all social and organizational problems. Challenging this view might be the key to our understanding of the shortcomings of current DSS and a first step toward an alternative framework.

1.1 Decision Support Systems: An Overview

Decision making, as an area of study, originates in organization science (Simon 1960). Decision Support Systems are computer technologies used to support complex decision making in organizations (Keen & Scott Morton 1978). Turban (1995) defines DSS as "*an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights.*" This definition applies to various types of DSS — data-driven, model-driven, group support system (GSS), etc. In the 1990's, there was a trend toward "intelligent DSS" (IDSS) and the incorporation of tools and techniques of Artificial Intelligence (AI). Shim et al. (2002) have discerned a recent trend toward the personalization of DSS user interface, the use of Web-based technologies, and ubiquitous computing.

There has been a close parallel between the evolution of the concept of DSS and the development of computer technologies and tools (Shim et al. 2002). In the era of data processing and management information systems (MIS), for example, the emphasis in DSS was on databases and data models. Later on, with the advent of expert systems and executive information systems (EIS), the scope of DSS extended to group and corporate levels. Then, the growing interest in knowledge bases brought about the notion of organizational knowledge management. Most recently, the expansion of the World Wide Web and wireless technologies is giving rise to web-based DSS and to new conceptualizations of decision making from multiple perspectives. In parallel with these, there have also been developments in the data component of DSS from data warehousing and data mining to the notion of data marts.

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Table 1 summarizes the development of DSS as it relates to the supporting technologies (Shim et al. 2002). As the table illustrates, this development has been dominantly bottom-up and technology-driven, with the available technical tools supporting the traditional concept of decision making as a basically rational process (Simon 1960). The techno-centric character of DSS thinking is best illustrated in the theory and practice of knowledge engineering.

Table 1
The Development of DSS in Relative to Technology

Stage	Period	Dominant DSS Concept	Technologies
I	1960's–1970's	Data modeling	Databases, MIS
II	1980's	Collaborative and Group Decision Support (GSS)	Knowledge bases, expert systems, EIS
III	1990's	Knowledge management	OLAP, data warehouse, data mining
IV	2000's	Web-based and active DSS	Internet, client-server tools, software agents

As a key activity in DSS (as well as knowledge management), knowledge engineering is the process of eliciting and modeling the putative knowledge that experts or scientists employ in making judgments in their area of expertise. The traditional "transfer view" of knowledge engineering treats elicitation and modeling as two successive and independent phases (Becu et al. 2003). Elicitation in this view is basically thought of as a process of extracting knowledge through interviews, monitoring, etc. and of encoding that knowledge using Protocol Analysis (Newell 1982). The same view dominated knowledge management (KM) for many years. Nonaka (1994)'s well-known quadrant model of KM is a paradigmatic example of this view, which underplays cultural and organizational aspects of knowledge management — e.g., issues of trust, rewards, and incentives — through a dominantly technological lens: capture and codify knowledge with experts systems; share knowledge with groupware and intranets; distribute knowledge with databases and desktop publishing; and create knowledge with computer-aided design (CAD), virtual reality, and so on (Ekbia and Hara, in press). In the alternative "modeling view" of knowledge engineering (Wielinga, et al. 1992), the elicited knowledge is organized through a pre-defined conceptual model and the experts are involved in the modeling phase, but a similar emphasis is put on knowledge capture without much attention to issues of trust, incentive, and commitment on the part of participants.

We believe that many of the shortcomings of current DSS, as pointed out, for instance, by Elgarah et al. (2002), are due to this techno-centric view. In an effort to reconceptualize decision making, this paper follows a top-down approach, starting with a new conceptual framework and then exploring the technologies and tools that can support it.

2. IN SEARCH OF A FRAMEWORK

As mentioned earlier, the development of DSS has been largely bottom-up and technology-driven, in the sense that DSS systems have evolved in such a way as to be able to accommodate the latest computer and information technologies of the time. Although this development has brought about certain changes in the way DSS is used and understood, at large, the technical orientation has undermined the possibility for deep reconceptualization of decision making. Alternatively, the following presents a top-down, concept-driven approach — that is, an approach that begins with an overarching conceptual framework and then finds suitable technologies and tools that would support and implement that framework.

For this purpose, the paper draws upon a number of prior frameworks from cognitive, organization, and social sciences — namely, sense-making, distributed cognition, and actor-network theory. This proposed framework is, therefore, far from novel. It contributes to ecology and ecosystem management by introducing ideas from other areas that, to the best of current knowledge, are previously unexplored in these fields. Its contribution to DSS consists of a new way of thinking about decision making from the individual, organizational, and technical perspectives, similar in spirit to what others have suggested earlier (Weick 1995, Elgarah et al. 2002).

The following sections propose a set of conceptual shifts on cognitive, organizational, technical, and normative dimensions, which set the foundation for the desired framework.

2.1 The Pragmatic Shift: From Problems in the Mind to Problematic Situations in the World

The original DSS concept defined by Gorry and Scott Morton (1971) was based on two previous works. The first was Anthony (1965)'s classification of management activities into 1) strategic planning by upper management, 2) management control by middle management, and 3) operation control by first line supervisors. The second work was Simon's (1960) decision-making framework, which consisted of intelligence (search for problems), design (development of alternatives), and choice (analyzing the alternatives and making a choice). Simon's

view has had a lasting impact on the development of DSS in at least two ways. One is through the idea of "bounded rationality," which basically portrays decision making as a weighing of alternatives according to some preset criteria. Indeed, it can be safely asserted that many subsequent models of decision making — e.g., optimization-based DSS (that involves three stages of formulation, solution, and analysis), multi-criteria decision analysis (MCDA), or the analytic hierarchy process (AHP) — are variations of the original Simon model, although they have become increasingly sophisticated in terms of the number and classification of involved criteria, in terms of mathematical formalisms, etc.

The second major impact of Simon's work is through the idea of "cognition as problem solving," which is mostly elaborated in his joint work with Allen Newell in Artificial Intelligence (AI), but its influence goes far beyond AI to areas such as organization and management science. A key tenet of the problem-solving paradigm is its emphasis on mental representations (or symbols or models) of external situations. According to this view, people deal with the outside situations by building (more or less) faithful models thereof in their "heads." Therefore, all thinking (e.g., decision making) consists mainly of the manipulation of these internal models and symbols. Problems are in our heads, as are solutions to problems.

The above view of cognition, thinking, and decision making has dominated DSS as well as ecosystem management until recently. However, alternative views are on the rise, some of which were examined earlier. A common tenet of most of these approaches is that rationality is not the modus operandi of decision making. The point is not that rationality is ill-conceived, but that the conditions under which it works best are relatively rare (Weick 2001: 34). Rationality prevails if the environment changes slowly, if there are few social groups, and if the situation is reasonably well-controlled by agents with central authority (Kling 1980: 90, 100) — all of which are rare in real environments.

Another common tenet of the new approaches is the idea, put simply, that problems are not so much in the head as they are in external situations. In other words, what we often have to deal with are "problematic situations," not problems as mental models of those situations. This means that problems do not present themselves as given, rather "they must be constructed from the materials of problematic situations which are puzzling, troubling, and uncertain" (Weick 1995: 9). In recent intellectual history, this idea goes back to pragmatism, founded by, among others, John Dewey, William James, Herbert Mead, and Charles Sanders Peirce. A problematic situation, according to pragmatists, is one which is "*disturbed, ambiguous, confused, full of conflicting tendencies, obscure, etc*." (Dewey 1940: 117). Thinking, therefore, consists of the process that would lead from such a situation to one which is less indeterminate, uncertain, obscure, and so on.

In the spirit of pragmatism, this paper proposes a shift of focus from the traditional view of problem solving in the head to the notion of dealing with problematic situations in the external world and of taking actions that would reduce the indeterminacy of those situations. What is the significance of this shift for DSS and for decision making in general? A number of things:

- By introducing activities into the picture, it emphasizes the *process* of decision making rather than its *product*
- By downplaying mental models, it reduces the cognitive load of deliberation on decision makers
- By starting from the external situation, it makes it more likely and probably easier for multiple decision makers to arrive at a common representation of the problem (which, as is argued, is a major step toward consensus)
- By incorporating indeterminacy in the picture, it provides a positive characterization of situations, rather than the negative characterization built into the notion of wicked problems [for more on this – Peirce's essay on "doubt"].

For practical purposes, one of the implications of this shift is that any decision-making process should involve a problem-setting phase (what Dewey calls the "institution of the problem") that would take us from a problematic situation to a problem. People often start with different understandings of a situation, and arriving at a common problem statement might indeed be a major step toward its solution. Dewey (1940: 119) says: "*Qualification of a problem as problematic does not, however, carry inquiry far. It is but an initial step in institution of a problem. A problem is not a task to be performed which a person puts upon himself or that is placed upon him by others — like a so-called arithmetical 'problem' in school work. A problem represents the partial transformation by inquiry of a problematic situation into a determinate situation.*".

2.2 The Constructive Shift: From Decision Making to Sense Making

"[*S]ensemaking rather than decision making may be the more central organizational issue. Whether there are decisions that need to be made and what those decisions might consists of are products of sensemaking. To be in thrall of decision making is to spend too much time on too narrow a band of issues that crop up too late after most of the important action is already finished*." (Weick 2001: 4)

DSS have traditionally focused on decisions as *products* at the expense of the *process* that gives rise to decisions. Even when the process is considered, it is deemed as fact-driven — that is, as one that starts with data, builds facts, weighs alternatives, and arrives at a decision. However, a rather different picture arises if close attention is paid to the process. To do that, this section draws upon the framework developed by Karl Weick, who characterizes sensemaking as a process that is (Weick 1995: chapter 2):

- Grounded in identity construction
- Retrospective
- Enactive of sensible environments
- Social
- Ongoing
- Focused on and by extracted cues
- Driven by plausibility rather than accuracy

Among these, retrospection and enactment are most relevant to the purposes discussed here, but other properties of sensemaking will also be explored throughout the discussion.

2.2.1 Retrospective Justification

Studies of decision making in juries have indicated that they are largely outcome-driven — "*The outcome comes before the decision*" (Garfinkel 1967: 114). That is, jurors do not seem to first evaluate the harm, then allocate blame, and finally choose a remedy. Rather, they first decide a remedy and then decide the "facts" from among alternatives that justified the remedy. In short, they retrospectively justify a decision that is being made on grounds other than (or beyond) facts. Garfinkel concludes from this study that: *"…decision making in daily life would thereby have, as a critical feature, the decision maker's task of justifying a course of action. The rules of decision making in daily life … may be much more preoccupied with the problem of assigning outcomes their legitimate history than with questions of deciding before the actual occasion of choice the conditions under which one, among a set of alternative possible courses of action, will be elected."* (pp. 114).

Failing to understand the role of retrospection leads to biases in people's understanding of situations — e.g., when knowing the outcome of a process the reasons for that outcome seem obvious, necessary or intended, rendering other options unimaginable.

2.2.2 Enactment

"*If men define situations as real, they are real in their consequences."* (Thomas & Thomas 1928)

Retrospection also highlights the interleaving of thoughts and actions. People do not face a situation as a given, rather they enact and produce the situations of which they are a part. As Garfinkel describes them, "*in the course of a career of actions, [people] discover the nature of the situations in which they are acting.… [T]he actor's own actions are first order determinants of the sense that situations have, in which, literally speaking, actors find themselves*" (1967: 115). This is the spirit of the constructivist shift suggested here. The active character of sensemaking is what makes it different from "interpretation," as it is commonly understood (Weick 1995: 13). Here the emphasis shifts from the question of "*what people know*" to the issue of "*how people go about knowing what they know*."

The failure to understand the active character of sensemaking has resulted in a great many futile efforts and projects. Some AI practitioners, for instance, have tried, rather unsuccessfully, to capture human common sense in huge knowledge bases, arguing that this will inevitably lead to intelligent computers. In other words, they assume that common sense consists of a certain amount of knowledge that can be codified and stored in a computer in the form of logical assertions. The fallacy of this assumption lies in its failure to understand the active character of sensemaking — it emphasizes the common aspect of commonsense and marginalizes the active process of making sense.

2.3 The Normative Shift: From Accuracy and Certainty to Plausibility and Transparency

The third major shift proposed here has to do with the values and criteria that should be used in a decision process. Traditionally, the emphasis in DSS has been on capturing, encoding, and providing as much knowledge as possible to decision-makers in order for them to be able to make informed, documentable, and responsible decisions (Pereira and Quintana 2002: 97). "Responsible" in this context often meant the use of best (expert) scientific knowledge in decision making, not necessarily socially responsible, "*because the social context would not explicitly be taken into account"* (ibid). Similarly, documenting the decision was considered a preamble for the legitimizing and quality assurance of the decision process. While these are important criteria, it is suggested that the emphasis be shifted toward the *plausibility*, *reasonableness*, and *coherence* of decisions as well as the *transparency* of the decision-making process. This shift would highlight the importance of meaningful (as opposed to informed) decisions and of reassuring and legitimate (rather than ensured and authoritative) processes.

Weick (1995: 55–61) provides some reasons "*why accuracy is nice but not necessary*" in the sensemaking

process — e.g., that people need to filter signal from noise in order not to be overwhelmed with data, that there is often a tradeoff between speed and accuracy, that there is always a subjective, interpersonal component present in any decision-making situation, that accuracy is pragmatic and project-specific, that it is impossible to guarantee accuracy prior to action, and so on. Weick concludes from this that what people need is not more information, but "*values, priorities, and clarity about preferences to help them be clear about which projects matter*" (p. 27).

On the other hand, those involved in management and policy-making have increasingly emphasized that, in matters of public or group concern, the quality and transparency of the process is no less important than the certainty and validity of the outcome. This is an overarching criterion for the framework proposed here as well.

2.4 The Technical Shift: From Technology as Enabler to Technology as Transformer

The final shift proposed here is a technical one. To motivate this, it is important to revisit the notion of "problem solving" and see what role technology can play in this. Following Hutchins (1995), problem solving is simply thought of as representing a problem so as to make the solution transparent. Hutchins uses the example of navigation to show how representational states are propagated from one medium to another by bringing the states of the media in coordination with one another (p. 117). In navigation, a problem is solved (i.e., a ship is docked in harbor) by moving from features of the outside world (the name, description, or visual experience of a land mark) to an analog image on the alidade to a digital figure on the gyrocompass card to bearing record on a log to an angle measurement on a Hoey scale to physical state of Hoey arm and finally to a navigation chart that determines the next course of actions in terms of speed, direction, and so on.

This example demonstrates why it is useful to think of cognition in the broad sense of "*the propagation of representational state across representational media*" (ibid). It also demonstrates how problem solving is a collective act distributed among *people*, *devices* (alidade, Hoey), and *technologies* (record logs, charts, etc.). Seen in this light, technologies are best thought of transformers, rather than amplifiers, of our cognitive abilities. Hutchins (1995: 154) puts the point this way: "*When we concentrate on the product of the cognitive work, cultural technologies, from writing and mathematics to the tools…. appear to amplify the cognitive powers of their users. Using these tools, people can certainly do things they could not do without them. When we shift our focus to the process by which cognitive work is accomplished, however, we see something quite different… The application of these abilities must be "organized" in the sense that the work done by each component ability must be coordinated with that done by others…None of the component cognitive abilities has been amplified by the use of any of the tools. Rather, each tool presents the task to the user as a different sort of cognitive problem requiring a different set of cognitive abilities or a different organization of the same set of abilities."*

In other words, "*these mediating technologies do not stand between the user and the task. Rather, they stand with the user as resources used in the regulation of behavior in such a way that the propagation of representational state that implements the computation can take place*" (ibid).

This view of technology is also in alignment with actor-network theory (Callon 1986, Latour 1987, 1999), which explains social and technological developments in an intertwined fashion, with both human and non-human elements (technologies) capable of affecting and shaping each other's behaviors.

3.0 DSS IN PRACTICE: TOOLS, RESEARCH, AND TRANSLATION

Decision Support Systems have been in use for many decades and in various arenas. The traditional environments of DSS use were mostly business corporations seeking to assist executives and managers in their tasks in an increasingly complex, data-laden, and uncertain environment. The utilization of DSS in other arenas — e.g., urban planning, natural resource management, and public affairs — is a more recent development, which has triggered new realizations of DSS that are more amenable to such decision-making environments. The trend toward social and participatory models of decision making exemplifies this development (Turoff et al. 2002, Pereira and Quintana 2002). Pereira and Quintana (2002), for instance, describe the decade-long development of DSS within a research group at the Joint Research Center (JRC) in Europe. They characterize this as a transition from technocratic to participatory DSS, and emphasize that, "*Newer DSS developments are still computer tools, carefully designed for the audience they aim at and placed into a social process instead of embedding the social process into the system*" (p. 95). As the authors point out, this is in line with the new styles of governance, arising from the science and governance initiative in Europe. The question is whether and to what extent these ideas are realizable in other parts of the globe (e.g., in the US), where a different style of governance might be at work.

For the last couple of decades, various federal and local agencies in the U.S. have found themselves in decision-making situations where other groups with

different views, interests, and goals are also involved. These situations require not only multidisciplinary research and computerized systems that can compute (i.e., encode, filter, organize, display, etc.) the huge amount of data typically resulting from such research, they also call for institutional support of a rather new quality. That is, they need organizations with the right mixture of expertise, technology, and stature that can *mediate* (in the broad sense of the word) among various players in a constructive, efficacious, and credible manner. For reasons to be explained shortly, we will refer to these organizations as *translators*. Whether business- or academic-oriented, translators should be well-prepared and equipped to play the role expected of them in these circumstances. A good part of this role can be characterized as *research* in a broad sense to be outlined next. In what follows, building on this broad notion of research as it applies to the U.S. situation, the paper characterizes the role of institutions that conduct such research often using DSS as a supporting technology.

3.1 Research: An Inclusive Activity

"Research is becoming an openly multidimensional and all-embracing activity that must contribute simultaneously not only to the production of certified knowledge, collective goods, competitive advantage and professional skills but also to a culture and to collective decision-making involving as many participants as possible." (Callon et al. 1997: 12)

Research is a largely misunderstood activity (Callon et al. 1997). Traditionally, research is understood on the basis of one of the two opposite models: the academic research model and the production-of-innovation model. The first model aims to expand the pool of knowledge, and uses the mechanisms of peer review, competition, and reward to allow scientists to exercise autonomy while being controlled by non-specialists. The second model is used in the management of projects intended to lead to the development of new products, services or production processes. In this model, the customer (users, consumers, public authorities) is in control, and researchers are not left to their own devices.

In their extensive study of research in Europe, Callon et al. find the above bipolar model insufficient, and propose a third model of research, called "*technological programs*," which is most frequently found in interventions funded by public authorities. In this model, research is a complex activity with at least five different functions:

1. Production and circulation of certified knowledge through peer review (published or embodied in instruments)
2. Product and process innovation through collaboration with industry
3. Production of public goods (power, prestige, well-being such as environment and health) as objectives of public authorities
4. Training of new workforce
5. Public understanding of science (partly to justify public spending on a project)

This broadened model of research applies to a set of activities that goes far beyond traditional notions. Item '3' in the above list, for example, constitutes a major part of the activities of public or private organizations engaged in environmental research, renewable natural resource management, urban planning, and the like. In distinction from conventional research (or from common conceptions thereof), the focus of this activity is a kind of "networking" — that is, the design and promotion of what Callon et al (1997) call techno-economic networks. These networks *"… link research and economics in such a way as to create the homogeneity required to facilitate and encourage the establishment of relations as well as their continued growth… In short, it is no longer a simple matter of producing knowledge or mobilizing skills in line with demand. The nature of the knowledge required and the nature of the innovations to be developed are determined simultaneously and are accompanied by the establishment of a collective. This brings together scientists from all disciplines, as well as engineers, marketing and financial actors, and representatives of the end users. The design of these networks, i.e. the identification of participants and the organization of their interactions, cannot be separated for the processes of acquiring basic knowledge and developing innovations. The choice of who belongs to or who is excluded from a network determines what know-how will be developed and the goods and services that will be produced"* (pp. 12-13)

Callon et al. (1997) characterize this web of activities as one of *evaluation*. *"In the network dynamic, it is ongoing evaluation of objectives, actors and results that allows timely changes of direction… Evaluation is an on-going management process that is deeply concerned with scientific and technical details, and with developing links between actors, but also with the results obtained and how well they meet the aims and objectives of the programme."* (pp. 15 -16)

Evaluation is thus a method of investigation to help inform all those involved in decision-making (p. 17). A major difficulty for those involved in evaluation is to create the right balance among different constraints and expectations: *"On the one hand, they must be capable of impartiality, of neutrality, objectivity even. However, at the same time they must be prepared to listen to the customers of the evaluation and include their ideas and*

recommendations in the decision-making process so that evaluation does not become simply a stylistic exercise. Evaluators must achieve just the right balance." (p. 18)

To achieve this balance, the authors propose four major conditions that should be imposed on evaluation: timeliness, relevance, credibility, and robustness. Timeliness has to do with ever present time constraints on projects, relevance has to do with a minimal agreement on terms of reference (which can often involve long discussions and negotiations resulting in reformulation of the issues and modification of their relative importance), robustness has to do with "*the capacity of evaluation to withstand criticism and to demonstrate its significance, with value placed on the quality of the methods used credibility has to do*" (p. 19), and credibility, which comes mostly with reputation and experience, is established differently in various countries — e.g., the British model of evaluation by professionals (by defining *best practices*), the EU model of panel of experts, and the guarantor model in France. In the U.S., evaluation is mostly done by institutions that are specially formed and equipped for this purpose. In the next section, these institutions are referred to as translators. The concept of research used henceforth applies to the inclusive notion outlined in this section.

3.2 Translation: Turning Ideas into Reality

The interdisciplinary character of research outlined above positions the institutions that conduct the research in a network of heterogeneous elements that include academic individuals and institutions, local and federal agencies, environmental activists and conservationists, software vendors, and so on. To characterize and define the role of these institutions in this complex web of goals, interests, attitudes, and languages, the following proposes the framework of *actor-network theory* (ANT).

Originating in sociology of science, actor-network theory is an evolving body of knowledge that is being applied to increasingly diverse fields of inquiry. In rough outline, ANT analyzes socio-technical processes in terms of networks where resources are concentrated in a few places ("*the knots or the nodes*") connected with one another by "*the links and the mesh*" (Latour 1987). A network, according to ANT, is comprised of heterogeneous "*actants*" the most durable of which — people, institutions, tools, texts, money, technologies, information, etc. — flow through the network, in a way defining and creating the nodes. Depending on the relative flow and concentration of these "*immutable mobiles,*" some nodes and actors may acquire a privileged status, rendering the situation "*irreversible*." That is, they find it possible to make autonomous choices that not only fall in line with those of the other actors but make it impossible to go back to a point where alternative possibilities exist. As some theorists with views similar to ANT have argued, this margin of maneuver can become very large if an actor succeeds to situate itself at the intersection of two or more networks that hardly overlap elsewhere. The crucial point to bear in mind is that, according to ANT, the form and identity of the actors, far from being inscribed in their nature, is defined by "*the relations in which they are located,*" and that "*they are performed in, by, and through those relations*" (Law 1999). In order to create and populate networks, actors often employ different devices — e.g., problematization, enrollment, *interessement*, or mobilization — the common objective of which is to "*translate*" an idea, through the identification of a problem or opportunity, into reality.

It is this notion of "translation" that is proposed to borrow from ANT for characterizing the role of the above-mentioned institutes in the network of relations in which they are situated. This notion of translation is remotely associated with the canonical meaning of going from one language to the other. In line with the broad concept of research described earlier, this notion of translation is an activity-oriented process that involves the identification of issues and problems, the recognition and enrollment of actors, the attraction and alignment of their interests, tapping into their expertise and knowledge, the mobilization of resources (tools, techniques, knowledge, etc.), and so on. This is indeed a multifaceted role that requires insight, preparation, expertise, experience, open-mindedness, to say the least. Callon et al. (1997) warn: *"To an outsider, evaluation may seem to be the application of commonsense or of readily obtainable knowledge, with the non-specialist just as well equipped as the co-called specialist. However, nothing could be further from the truth. Experience shows that amateurism can lead to disasters, such as a lack of tact in managing decision-making processes, favoring certain tools and bias towards the expectations or the behaviors of scientists or civil servants. Evaluation is, in fact, one of the most difficult skills there is. It requires a good command of several disciplines together with the self-confidence that comes from accumulated experience*" (p. 20)

3.3 DSS as Research and Translation Tools

Having characterized *research* and *translation* in the broad sense outlined above, it is time to describe the role of DSS tools and technologies in these activities— that is, understanding DSS as tools for research and translation. This role will not necessarily be the same as the role of DSS in business, for instance, where a different set of criteria might be at work. The difference in roles might, in turn, lead to a difference in tools and technologies in terms of usefulness, effectiveness, and suitability. For example, while data mining tools that help with pattern

discovery might be very useful DSS tools in business, they do not serve much of a purpose in research. Similarly, a participatory social DSS suitable for a European style of governance, or a Multi-Agent Based System using game playing, might not be good candidates as research tools. The question is, *what types of DSS tools are suitable for this purpose*?

Preceding sections provided an outline of a conceptual framework and suggest supporting methodologies that are believed to fit this purpose. The next task is to come up with a set of features and properties of tools that can implement these concepts and frameworks in the context of *research conducted by translators*. In determining these features, it is important to keep in mind the criteria delineated throughout — namely, the resilience of the socio-ecosystem and the *transparency*, *plausibility*, and *credibility* of the decision-making *process*. But it is also important to be explicitly aware that different social and organizational contexts call for different properties and features for tools. Although this context-dependence of tools makes generic design challenging, maybe impossible, it makes the close coupling of technologies and their environment more easily achievable.

CONCLUSIONS

Decision support systems have demonstrated their effectiveness in arenas where the mandates of the situation are beyond the individual's grasp and judgment. However, the growing complexity of such situations demands a tight coupling of humans and technologies that seems to surpass the capabilities of current DSS. We argued in this paper that current systems are limited in their capabilities for a number of reasons: i) their reliance on a mentalistic view of cognition; ii) their fundamental assumption of a principally rational model of decision making; iii) their emphasis on criteria such as accuracy and certainty that are not fully attainable in most real-life situations; iv) the loose coupling between technologies and their embedding environments (including human beings). We also demonstrated that the development of DSS in the last few decades has been largely bottom-up — that is, it has typically moved from tools to techniques to concepts. To overcome these limitations, we adopted a top-down approach and suggested a number of shifts, which were outlined throughout the paper.

The top-down approach and the proposed shifts made it possible for us to revise some of the fundamental assumptions of current DSS. In particular, it allowed us to understand and articulate decision-making as a constructive process of sense making that can potentially lead to alternative realities (rather than the rational weighing of current alternatives), as the retrospective justification of perceived outcomes, and as the coordination among various actors (people, institutions, technologies, documents, and so on). The constraints of present information-rich but fuzzy and uncertain decision environments also led us to postulate transparency and plausibility as norms that should govern decision-making.

Our discussion of the technical and practical aspects of decision-making brought up the central question of how to realistically implement the methodology proposed in this paper and how to most effectively integrate new technologies into the decision-making process. We introduced the notion of a translator as an institutional role that can be played by scientifically versed, technically equipped, and experientially competent organizations who conduct research in the broad sense of a multifaceted and inclusive activity. We also emphasized, as an important pragmatic consideration, the match between technical tools and their embedding environment. We would suggest that various arenas — academic, business, government, participatory (grass-root,) non-profit, and so on — call for different DSS implementations and tools, and that the one-tool-fit-all view of DSS is misguided. Therefore, despite our desire to come up with a set of universal properties and features for DSS, we cannot go beyond the most general outlines of such properties. Each particular context demands its own specific properties and features.

We are aware that the set of concepts, methods, and tools developed and proposed here might be too broad to warrant concrete and particular implementations, but we do hope that, by offering a new perspective, they open up new possibilities for diverse and contextually specific tools and designs.

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